inches in length, strongly oboval, sharply pointed at base, covered with coarse, very closely applied, irregularly ascending, branching fibers converging radially at the three pores; shell an eighth to a quarter of an inch thick, very hard; albumen white, hollow at center.

The foregoing description is based on material gathered in the forest and on palms examined there. In clearings where this palm has been allowed to remain, its aspect is quite different from that of the shade form, as it appears much more compact because the petioles and blades of the leaves are shorter, the latter with the groups of pinnae more closely placed on the rachis. Young palms of this species show a characteristic development of the leaves in that the pinnae almost never are separated; leaf-blades as much as four or five feet long remaining entire or at most with but one or two divisions on each side.

The type specimens deposited in the U. S. National Herbarium under numbers 474451–474457, were collected in the forest at Rio Hondo, Plains of Santa Clara, Costa Rica, altitude 100 meters, May 7, 1903, by O. F. Cook and C. B. Doyle under their number 584. Specimen 474452 is an inflorescence with flowers not quite old enough to open, the other specimens apparently are portions of a single leaf. Photographs of this species, made by O. F. Cook and C. B. Doyle in 1903 and H. Pittier in 1906, have been studied, parts of several of these being herein reproduced, and in addition the writer collected fruiting and leaf material at Cairo, Costa Rica, in 1937 and 1938 and sent it and seed to the Division of Plant Exploration and Introduction, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Plants from these seeds were distributed to plant experimenters in Florida in 1938 under P. I. number 123380 with the tentative name *Astrocaryum polystachyum*, a name which appeared in the Biologia Centrali-Americana in 1885 without description and which has not yet been thus supported.

Although it is too soon to be certain that this handsome tropical woodland palm will survive and become a part of Florida's subtropical horticulture the growth of these seedlings has been more rapid than with other species of the genus tested at the U. S. Plant Introduction Garden, near Miami, and promises well for the future.

PLANT PHYSIOLOGY.—*Hydrocyanic acid content of sorghum varieties.*[1]

JAMES F. COUCH, REINHOLD R. BRIESE, and J. H. MARTIN, Bureaus of Animal and Plant Industry, Washington, D. C.

Sorghum[2] has long been known to be poisonous to animals under certain conditions. The quantity of cyanogenetic glucoside in this plant is one of the factors that determine its toxicity. A large number of sorghum varieties are grown in the United States for feeding to livestock, any one of which may be eaten by animals while in a con-

[1] Cooperative investigation between the Pathological Division, Bureau of Animal Industry, and the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture. Received November 18, 1938.

[2] (Sorghum vulgare, Pers.)

dition to produce poisoning. It is of interest to know to what extent the content of glucoside and, consequently the quantity of hydrocyanic acid, that may be liberated under appropriate conditions, is determined by the variety grown, and whether the differences observed are inherent in the variety or are due to responses to fluctuating environment.

Previous studies (8) have shown that the HCN content of a sorghum variety depends upon the part of the plant analyzed, the age of the tissues, and the growing conditions. Consequently, the relative HCN content of different varieties cannot be determined accurately with only a few samples grown at one point.

It seemed desirable to analyze sufficient samples of a considerable number of varieties grown at several places in the United States to overcome, insofar as possible, some of the discrepancies due to accidental or environmental factors that might affect determinations made from single collections and to determine the effect of certain environmental factors on the relative HCN content of the varieties. Samples were collected in two years, 1936 and 1937, and the analyses are summarized in this paper.

REVIEW OF LITERATURE

Other workers have reported data concerning the relative hydrocyanic acid content of different varieties of sorghum. Brünnich (2) reported 2 to 2.5 times as much HCN in "Imphee" as in Early Amber sorgo. Schröder and Damman (10), in the Argentine, found sorgo slightly higher in HCN than Johnson grass and nearly twice as high as in broomcorn (varieties not stated). Furlong (6) determined the HCN content of sorghum (Guinea corn) and millet at various stages of growth and found the former higher than the latter in ratios varying between 1.5 to 1 and 2.44 to 1. Francis (5) found less HCN in normal mature kafir leaves than in second-growth Sudan grass or in Sudan grass that was 10 inches high. The plants were, however, not of the same age or height and therefore not comparable. Willaman and West (12) published figures indicating that feterita produced considerably more HCN than Orange sorgo. Later (13) they reported figures showing that, except for plants 33 days old, Early Amber sorgo yielded slightly less HCN than "Southern Cane" under Minnesota conditions. Swanson (11) found the following quantities of HCN in the varieties stated: Kafir 36, sorgo 21, and Sudan grass 16 mg per 100 g of green tissue. With special treatment Red Amber yielded 59.5 and sorgo 48 mg of HCN. Collison (3) published an extensive comparison of the HCN content of different varieties. He analyzed plants 12 to 24 inches high of 17 varieties and two samples of mature hegari and feterita, all grown in Florida. The highest HCN content found was 3.8 mg per 100 g in mature hegari, which is extremely low. Mature feterita gave 3.6 mg. Of the 12 to 24-inch samples, hegari yielded the highest, 3.7 mg, Blackhull kafir was second with 3.3, feterita third with 3.2, and Brown kaoliang fourth with 3.1. Amber sorgo, Japanese Cane, and Napier grass yielded no HCN. Orange sorghum and a milo hybrid were low with 0.75 and 0.2 mg. respectively. Other varieties ranged from 1.6 to 2.6 mg. Piedallu (9) found Early Minnesota Amber sorgo and broomcorn richer in HCN than "S. douro" and Johnson grass. Finnemore and Cox (4), working in Australia, made a number of analyses of sorghum varieties, Sudan grass, and sorghum-Sudan grass hybrids, taking specimens of each at intervals during the growing period. Comparison of the figures for the green plants 64 days old shows the following order of HCN content: Feterita 75, Gooseneck sorgo 69, White African sorgo 45, Sumac sorgo 35, milo 33, Cowper sorgo 25, Collier sorgo 19, Saccaline sorgo 11, and Sudan grass 12 mg per 100 g green weight. The sorghum-Sudan hybrids gave 7 to 27 mg of HCN.

PRESENT INVESTIGATIONS

Environmental Conditions.—Sorghum samples were collected from six stations in the southern Great Plains in 1936 and 1937. The following representatives of the Bureau of Plant Industry grew the sorghums and collected the samples for analysis: for the Division of Cereal Crops and Diseases: J. J. Curtis at Akron, Colo., A. F. Swanson at Hays, Kans.; J. B. Sieglinger at Woodward, Okla.; J. C. Stephens at Chillicothe, Tex.; for the Division of Dry Land Agriculture: B. F. Barnes at Dalhart, Tex.; D. R. Burnham at Tucumcari, N. Mex. The sorghums were grown by the Division of Cereal Crops and Diseases in cooperation with the Colorado, Kansas, New Mexico, and Texas agricultural experiment stations and with the Division of Dry Land Agriculture, Bureau of Plant Industry. The seed used was from previous crops at the station, nearly all from self-pollinated (bagged) heads. Named varieties grown at different stations apparently were identical in type and origin, except for three varieties noted below, although some unconscious selection may have occurred in obtaining seed heads. The feterita samples were of the common type (C. I.[3] 182) at Hays, Woodward, and Tucumcari, and of the Spur variety at Chillicothe. The Spur variety is later and more leafy than common feterita. All of the hegari were identical in appearance, but the lot grown at Woodward (C. I. 750) was from a later introduction from the Anglo-Egyptian Sudan than the lot (C. I. 620) grown at the other stations. The Dwarf Yellow milo grown at Chillicothe (F. P. I.[4] 18684) appears to be identical with that grown at the other stations (C. I. 332) but the origin may be different. Three kafirs, Western Blackhull, Texas Blackhull, and Sharon are indistinguishable in growth habit or appearance but they were selected from farmers' fields of rather impure kafir in three different States. The wide differences in the rank for HCN content shown later for these three otherwise similar strains may indicate some inherent differences. However, they were not sampled under comparable conditions.

Altitudes.—The altitude in feet at the stations is as follows: Akron, Colo., 4,560; Hays, Kans., 2,000; Woodward, Okla., 2,002; Dalhart, Tex., 3,978; Chillicothe, Tex., 1,406; and Tucumcari, N. Mex., 4,158.

Soils.—The soil at Akron, Colo., is a dark-brown sandy loam underlain with clay at depths of 2 feet or more in most places. At Hays, Kans., the soil is a dark-gray to black loam of the Hays series underlain with a slightly lighter-colored clay loam and clay and is a typical chernozem soil. The soil at Woodward, Okla., is a sandy loam varying in thickness from 1 to 4 feet overlying a reddish clay subsoil and is classed as Amarillo sand. At Dalhart, Tex., the soil is a grayish sandy loam overlying a dark reddish-brown loam or clay loam of the Springer series and has been subjected to considerable dust blowing. The soil at Tucumcari, N. Mex., is a loose reddish-brown sandy loam of the Otero series that blows readily when unprotected by vegetation. The soil on Texas Substation No. 12, Chillicothe, Tex., is mostly a dark reddish-brown clay loam of the Vernon series.

Weather.—The mean monthly temperatures at the six stations for 1936 and 1937, compared with long-time averages for the five months, May to September, inclusive, are shown in Table 1. The precipitation for the same months is presented in Table 2. Temperatures were above average in 1936 and 1937 at all six stations, July and August being especially hot during the growing season. Precipitation for the five months was materially below average in both years at Hays, Kans., Dalhart, Tex., and Woodward, Okla., and in 1937 at Akron, Colo.,

[3] C. I. refers to accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

[4] F. P. I. refers to accession number of the Division of Plant Exploration and Introduction, formerly Office of Foreign Plant Introduction.

TABLE 1.—MEAN MONTHLY TEMPERATURE IN °F, DURING THE GROWING SEASON IN 1936 AND 1937, AND THE AVERAGE MONTHLY TEMPERATURE AT SIX STATIONS

	May	June	July	August	September	Average
1936						
Akron, Colo.	60	70	79	74	63	69
Hays, Kans.	66	76	85	84	71	76
Dalhart, Tex.	65	75	79	79	67	73
Tucumari, N. Mex.	68	77	79	80	68	74
Woodward, Okla.	69	80	87	88	72	79
Chillicothe, Tex.	74	84	86	88	76	82
1937						
Akron, Colo.	59	66	75	77	65	68
Hays, Kans.	67	75	82	84	70	76
Dalhart, Tex.	66	73	79	80	70	74
Tucumcari, N. Mex.	68	74	80	82	72	75
Woodward, Okla.	71	77	86	86	73	79
Chillicothe, Tex.	75	80	86	86	77	81
Average						
Akron, Colo. (1912–1937)	56	67	74	71	62	66
Hays, Kans. (1893–1937)	62	72	79	78	69	72
Dalhart, Tex. (1906–1937)	62	72	78	76	68	71
Tucumcari, N. Mex. (1915–1937)	65	75	79	77	70	73
Woodward, Okla. (1914–1937)	67	77	82	81	73	76
Chillicothe, Tex.	71	80	84	83	75	79

and Chillicothe, Tex. The months of June, July, and August were very dry at Chillicothe in 1936. The precipitation at Tucumcari, N. Mex., was slightly above average both years.

The season of 1936 in the Great Plains was characterized by ex-

TABLE 2.—MONTHLY AND SEASONAL PRECIPITATION DURING THE GROWING SEASON IN 1936 AND 1937 AND AVERAGE MONTHLY PRECIPITATION

	May	June	July	August	September	Total
1936						
Akron, Colo.	3.51	3.04	1.85	2.17	3.03	13.60
Hays, Kans.	5.40	.60	.60	1.89	1.87	10.36
Dalhart, Tex.	3.67	2.44	1.49	.25	1.19	9.04
Tucumcari, N. Mex.	1.74	2.01	4.40	2.02	1.42	11.59
Woodward, Okla.	5.21	2.37	.23	.54	3.53	11.88
Chillicothe, Tex.	2.59	1.22	.46	0	13.67	17.94
1937						
Akron, Colo.	1.26	2.40	2.38	1.13	1.65	8.82
Hays, Kans.	1.73	1.98	4.28	2.58	1.71	12.28
Dalhart, Tex.	5.86	1.23	1.68	1.27	1.27	11.31
Tucumcari, N. Mex.	5.72	2.42	.87	.86	2.09	11.96
Woodward, Okla.	2.37	1.68	.51	2.28	3.91	10.75
Chillicothe, Tex.	1.50	2.63	1.81	2.91	.99	9.84
Average (24 or more years)						
Akron, Colo. (1908–1937)	2.85	2.40	2.57	2.19	1.46	11.47
Hays, Kans. (1906–1937)	3.07	3.77	2.71	2.95	2.02	14.52
Dalhart, Tex. (1908–1937)	2.82	3.08	2.30	2.58	1.43	12.21
Tucumcari, N. Mex. (1905–1937)	2.21	2.02	2.40	2.91	1.38	10.92
Woodward, Okla. (1914–1937)	3.47	2.96	1.84	2.44	2.75	13.46
Chillicothe, Tex. (1906–1937)	3.20	3.16	2.30	2.37	2.97	14.00

treme drought and high temperatures. Rains during May were ample for securing stands and maintaining early growth of sorghums. In general, the rains ceased about the first of June and sorghums having exhausted the available soil moisture, began showing the effect early in July at several stations. Showers at Akron, Colo., about July 11 and also prior to August 8 at Hays, Kans., prior to August 3 at Dalhart, Tex., and at Tucumcari, N. Mex., between August 25 and September 1, maintained or revived the plants somewhat. Plants were suffering from a shortage of moisture at Akron, Colo., on July 25; at Chillicothe, Tex., on July 14; at Tucumcari, N. Mex., on August 5; at Dalhart, Tex., after August 12; at Hays, Kans., on August 20; and at Woodward, Okla., on August 5. Later in the season, in September, ample rains fell at Chillicothe, Woodward, and Akron, but this moisture came too late to produce normal crop development, particularly in view of the early frosts. The crop at all stations thus suffered severely from drought.

In 1937, heavy rains occurred during the latter part of May at Dalhart and Tucumcari, but May rainfall was below average at the other four stations. Sufficient moisture was available for germination and fair early growth of the sorghums at all stations, but drought beginning after the middle of June at most of the stations affected the growth and development of the plants. Rainfall in July was below average at all stations except Hays and in August at all stations except Chillicothe. The crop was greatly retarded and stunted by drought at Dalhart, Tucumcari, and Hays, and growth was delayed at Woodward until rains came in September.

EXPERIMENTAL METHODS

Samples were collected at intervals during the growing season from most of the varieties studied. In some cases the number of collections was limited by a scarcity of material or by the condition of the crop but, wherever possible, samples were taken at intervals from the time the plants were 6 to 10 inches high until growth was stopped by frost.

During 1936 whole plants were sliced into small sections, the material intimately mixed, and duplicate 100 g samples weighed into pint preserving jars, covered with preservative, and shipped to the laboratory at Washington, D. C., where they were analyzed as soon as possible, 0 to 12 days, after arrival. After some experimenting with preservatives, 15 percent alcohol was used, and all figures obtained by the use of other preservatives in 1936 were discarded as inaccurate. It is now known that 15 percent alcohol is not an ideal preservative and that data obtained from samples preserved in it for longer than 7 to 10 days may be quite inaccurate. However, the data have a certain value for comparative purposes and indicate the relative proportions of HCN yielded by the different varieties.

In 1937, some important changes in collection and preservation were made with the result that the figures obtained from these collections are regarded as much more accurate than those for 1936. The plants were minced through a food chopper, mixed thoroughly, and the weighed samples preserved in mercuric chloride solution (1) in the proportion of 1 g of mercuric chloride to 100 g of fresh plant material. Experience with this preservative indicates that, in this strength, excellent preservation may be obtained for as long as six months. The samples were shipped to the laboratory and were analyzed four to six weeks after collection. The technique of analysis is described elsewhere (1).

In 1936 no moisture determinations were made on the collected samples and the figures obtained refer to the HCN content of green plant only. In 1937 moisture determinations were made on all samples except at Akron where the samples were only air-dried. For that year figures are available for the HCN content of fresh tissue and calculations are recorded on a moisture-free basis at all stations except Akron, where the air-dry basis was used.

VARIETAL DIFFERENCES

The average HCN content of all samples of the varieties collected in 1936 at each of the six stations is shown in Table 3. The figures are averages of eight collections made at Chillicothe, Tex., eight at Hays, Kans., four at Tucumcari, N. Mex., two each at Woodward, Okla., and Akron, Colo., and in part at Dalhart, Tex. Data from Akron are shown for two separate plantings, one on fallow land and the other on land in which moisture was very deficient, because Sudan grass had been grown the previous year. At Dalhart, samples were taken from two plantings made on June 4 and June 15. Five collections were made from the former and two from the latter planting.

The weighted average for each variety was calculated from the samples taken at the same time as were samples of Sumac sorgo. Since some samples were lost by breakage during transit and a few were discarded for insufficient preservation the figures for the corresponding Sumac sorgo samples were excluded from the averages. The varieties are listed in the order of comparative percentages. The

Table 3.—Average hydrocyanic acid content of 31 sorghum varieties grown at six stations in 1936

Variety	Samples	Hydrocyanic acid in 100 grams of fresh tissue								Weighted average of comparable samples		
		Akron, Colo.		Chillicothe, Tex.	Dalhart, Tex.		Hays, Kans.	Tucumcari, N. Mex.	Woodward, Okla.			
		On fallow	After Sudan grass		June 4	June 15				Variety named	Sumac in same tests[1]	Percentage of Sumac
	Number	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg
Feterita	41			49.7			42.3	16.9	81.0	44.5	33.5	132.8
Dawn kafir selection	13						31.9			31.8	27.7	114.8
Scarborough broomcorn	4								71.3	71.3	62.1	114.8
Wheatland	4	15.4	21.0							18.2	16.1	113.0
Chiltex	14			44.5						44.5	39.6	112.4
Western Blackhull kafir	16						33.8			33.8	30.3	111.6
Red Amber sorgo	14			39.8						39.8	37.8	105.3
Standard Blackhull kafir	4								66.4	66.4	63.1	105.2
White darso	4								66.1	66.1	63.1	104.8
Hegari	38			33.9	30.5	40.9			70.2	33.9	32.8	103.4
Sumac sorgo[1]	58	13.2	18.9	35.1	27.5	36.9	26.5	17.1	63.1	29.9	29.9	100.0
Sharon kafir	4								57.1	57.1	63.1	90.5
Finney milo	12							11.0	65.6	29.2	32.4	90.1
Honey sorgo	32			38.8	18.6	23.2		12.9		26.3	30.0	87.7
Atlas sorgo	37	9.2	12.0		21.2	27.5	30.0	11.0	49.7	26.8	31.3	85.6
Early Kalo	4	9.5	16.4							12.9	16.1	80.1
Evergreen dwarf broomcorn	4	7.9	17.7							12.8	16.1	79.5
Texas Blackhull kafir	24			29.1				9.0		22.5	28.7	78.4
Dawn kafir	12	8.1	15.9					13.6		13.1	16.8	78.0
Darso	27			28.9	14.9	26.8		17.8	65.9	30.1	38.9	77.4
Dwarf Yellow milo	44	13.5	14.9	30.2	16.3	18.5	25.6		55.8	27.2	36.3	74.9
Pink kafir	4	10.5	24.6							12.0	16.1	74.5
Kansas Orange sorgo	52	7.1	18.4	26.9	19.9	24.0	24.0	12.7		21.4	31.1	68.8
Acme broomcorn	11				17.5			14.4		15.2	22.6	67.3
Leoti sorgo	30	7.6	10.5		12.1	11.6	20.4			16.4	26.1	62.8
Freed	4	7.1	12.2							9.6	16.1	59.6
African Millet sorgo	25			24.9	14.2	19.2				21.4	36.3	59.0
Quadroon	12			22.1						21.4	36.9	58.0
Black Amber sorgo	4	9.0	8.1							8.5	16.1	52.8
Sunrise kafir	14				13.9	15.8			30.5	18.6	39.0	47.7
Early Red kafir	14				11.7	10.0				11.4	29.6	38.5

[1] Early Sumac sorgo at Akron, Dalhart, and Hays.

number of samples of some varieties was limited and the reliability of the average HCN contents shown for these varieties is questionable. Comparable averages based upon 10 to 16 or more samples, however, should indicate the relative HCN content of the varieties with considerable dependability. The data from Woodward, Okla., are based on only two collections made on August 17 and 29 at a time when the HCN content of the plants was at a high seasonal level. At the other stations, with the exception of Akron, the data include those from collections made in September and October when the HCN content normally is low.

A considerable difference in the HCN producing capacity of the varieties is indicated in Table 3. Varieties like feterita, Chiltex, and hegari tended to produce relatively large quantities, and Leoti sorgo, Early Red kafir, Dawn kafir, and Acme broomcorn produced one-quarter to one-third as much. If the lethal level of HCN in fresh sorghum for sheep be assumed as about 20 mg per 100 g, in accordance with the suggestion of Hindmarsh (7), which in the main agrees with some unpublished results of the Bureau of Animal Industry, then the average sample of 20 of the 31 varieties would be likely to produce poisoning if livestock gained access to the growing plants. However, since the figures are averages, and include data from mature plants that normally contain little HCN, it should be emphasized that any and all of the varieties listed may be highly dangerous at certain stages of growth, and none is to be regarded as always nontoxic.

The quantities of HCN in the varieties do not show the same relations when the varieties are grown at different stations. At Chillicothe, Honey sorgo was a tenth higher than Sumac sorgo, a fourth lower at Tucumcari, and a third lower at Dalhart. Feterita was only slightly lower in HCN than Sumac sorgo at Tucumcari but was distinctly higher at Chillicothe, Woodward, and Hays. HCN in Atlas was two-thirds to four-fifths that of Sumac sorgo except at Hays, where it was 13 percent higher. Darso was a little higher than Sumac sorgo at Woodward and Tucumcari but only half as high in the June 4th planting at Dalhart.

The ranking of varieties in order of HCN content in Table 3 is not in general agreement with opinions based upon casual reports of sorghum poisoning on farms. Most cases of sorghum poisoning appear to occur in fields of kafir and sorgo. The Black Amber variety is the leading sorgo in the northern half of the United States, including South Dakota, Nebraska, Colorado, and northern Kansas, sections where poisoning seems to be of frequent occurrence. Analyses of

Black Amber from Akron show it to be relatively low in HCN. This, however, may be a result of a more advanced stage due to the relatively early maturity of the variety. Reports of poisoning in animals from eating hegari are rare but this may be due to the fact that very little hegari is grown north of Oklahoma. Milo and broomcorn usually are headed from standing stalks which are left in the field. The fields of these sorghums often are pastured after harvest, and reports of poisoning on milo and broomcorn are extremely rare, although analyses indicate that both contain toxic quantities of HCN at times. It is probable that sufficient seed and mature leaves and stalks are consumed along with the young second growth leaves so that dangerous quantities of the latter are avoided.

TABLE 4.—HCN CONTENT IN MG PER 100 G OF DRIED LEAVES AND GREEN PLANTS OF SORGHUM VARIETIES COLLECTED AT CHILLICOTHE, TEX., SEPT. 11, 1936

Variety	Moisture content of dried leaves	HCN content		
		Dried leaves	Whole green plant	
			Wet basis	Dry basis[1]
	percen	mg	mg	mg
Sumac sorgo	9.33	91.6	48.1	192.4
Darso	9.39	86.9	29.1	116.4
Spur feterita	8.94	71.1	72.8	291.2
Hegari	9.50	59.1	51.2	204.8
Chiltex	8.55	54.8	59.1	236.4
Texas Blackhull kafir	9.69	52.5	36.2	144.8
Kansas Orange sorgo	10.34	43.2	43.1	172.4
Red Amber sorgo	8.77	40.1	32.7	130.8
Sourless sorgo	8.72	38.5	35.0	140.0
Dwarf Yellow milo (F.P.I. 18684)	6.64	31.2	38.3	153.2
Honey sorgo	6.96	24.9	51.3	205.2
Quadroon	8.32	20.6	30.0	120.0

[1] Calculated on the basis of the assumed approximate average moisture content of 75 percent in the green plants.

Table 4 shows a comparison of the HCN content of fresh green plants and dried leaves of the same varieties collected at Chillicothe, Tex., on September 11, 1936. Samples were taken of whole plants and preserved for analysis and, at the same time, leaves of the same varieties were selected and dried. The varieties are listed in order of the HCN content of the dried leaves. Sumac sorgo was highest in HCN in the dried leaves and fifth in content in the green plants. Spur feterita was highest on the basis of the green whole plants, but was third in HCN content of the dried leaves. Darso, which was lowest in HCN in the green whole plants, was second high on the basis of the dried leaves. While the fresh plants of hegari and Honey sorgo had about the same HCN content, the dried hegari was more than twice as high as Honey sorgo. Chiltex was second in the green whole plant and fifth with respect to the dried leaves. These data suggest not only that the comparative quantities of HCN differ in the dried leaves as compared with the whole plant but also that varieties may lose HCN at different rates or in varying degrees on drying. Thus, hegari and Chiltex lost a larger percentage than did Sumac sorgo and much less than did Honey sorgo. Darso lost comparatively little, while Quadroon, which was about equal to darso in the green state, lost the greater part of its HCN when dried.

The toxicity of the dried samples is of interest. Several of the varieties were force-fed to sheep. Feterita, hegari, and darso, fed in doses calculated to contain from 1.5 to 2.5 minimal lethal doses of HCN, produced serious symptoms of poisoning from which the animals recovered after treatment. Texas Blackhull kafir produced symptoms of poisoning when fed forcibly in doses of 0.9 to 1.1 m.l.d. from which the sheep recovered without treatment. It appears that dried sorghums containing somewhat less than 52.5 mg of HCN per 100 g are potentially dangerous in hay. Of the varieties listed in Table 4, Dwarf Yellow milo, Honey sorgo, and Quadroon might possibly be considered only slightly dangerous while the other varieties contained sufficient HCN to produce more or less serious symptoms, and several of the varieties were sufficiently high in HCN to cause very serious effects, if not death, if eaten in the quantities usually consumed at a single feeding under the conditions of the above experiment.

During the season of 1937 attention was concentrated on a few varieties. Feterita, Sumac sorgo, hegari, and Dwarf Yellow milo were grown at each station. Texas Blackhull kafir was grown at Chillicothe, Dalhart, and Tucumcari, Western Blackhull kafir was grown at Hays, Sharon kafir at Woodward, and Dawn kafir at Akron. The first three varieties of kafir are indistinguishable morphologically and in time of maturity, although it is possible that they may differ in HCN content. The data in Table 3 suggest that these three kafirs may differ in HCN content. Collections of Sudan grass were made at Akron, Chillicothe, and Woodward. Hegari was sampled as a whole plant. With the other varieties, the whole plant was sampled until the flag leaf appeared. After that only the leaves were sampled, as it had been ascertained that the stalks contain so little HCN that they are not important in animal poisoning. Collections were continued at most of the stations until frost occurred. The data are fairly complete for the different varieties from the seedling to the ripe stages of growth. Comparable collections of feterita and Sharon kafir were also made from the plots grown by the writers at Arlington Farm, Arlington, Va. Some of these samples were analyzed immediately upon collection, as well as after preservation in mercuric chloride solution. The results presented in Table 5 represent the averages for each variety at each station, with a general average for all of the stations. Dawn kafir, grown only at Akron, is not included in the averages for the kafirs. The data are calculated to mg of HCN per 100 g of dried

Table 5.—HCN content of sorghum varieties at six stations in 1937

Variety	HCN content of 100 g dry matter							
	Akron	Chillicothe	Dalhart	Hays	Tucumcari	Woodward	Average	Percentage of Sumac
	mg	mg	mg	mg	mg	mg	mg	mg
Young Whole Plants								
Feterita	200.3	156.3	212.9	199.1	176.4	150.9[1]	182.6	95.5[5]
Sumac sorgo	203.2	171.8	239.3	216.6	165.7	138.4[2]	172.5	100.0
Hegari	121.6	107.2	209.6	181.4	183.2	144.2[2]	157.8	84.4
Dwarf Yellow milo	182.2	112.0	168.8	158.9	128.2	107.2[3]	142.8	75.6
Kafir	133.2[1]	114.5	107.6	138.0	114.7	88.4[2]	112.6[4]	61.7[4]
Sudan grass	161.1	121.2	—	—	—	48.2	110.1	58.9
Fully-developed Leaves								
Feterita	197.1	133.4	156.6	217.1	141.5	146.3	165.3	95.2
Sumac	213.1	202.3	152.7	219.8	80.4	—	173.6	100.0
Hegari	193.0	161.6	—	208.1	110.7	—	168.3	96.9
Dwarf Yellow milo	154.9	72.6	79.3	123.1	64.4	—	98.8	56.9
Kafir	166.6[1]	69.7	50.5	136.9	87.3	—	86.1[4]	59.6[4]
Average of all	175.1	138.4	152.8	179.9	125.3	111.0	147.1	—

[1] 3 collections.
[2] 6 collections.
[3] 4 collections.
[4] Dawn kafir, not included in averages.
[5] Adjusted to comparable samples of Sumac sorgo from Woodward.

plant, air-dried in the case of Akron. These figures also were calculated to a common basis, taking Sumac sorgo again as a standard and calculating each station separately.

In general, the results are similar to those obtained in 1936. Feterita hegari, and Sumac sorgo are high in HCN while milo and the kafirs are low. The principal change is the change in position of Sumac sorgo from third place among the varieties grown at more than one station in 1936 to first in 1937 both for young whole plant and for leaves. This relationship was maintained at all of the stations except at Tucumcari, where Sumac was lower than both hegari and feterita both as young whole plant and as leaves, and at Dalhart where, as leaves, it was below feterita. At all stations milo and the kafirs were relatively low except Dawn kafir, grown only at Akron, Colo., the average for which is not strictly comparable with the averages for other varieties grown at five or six stations.

Selection for low hydrocyanic acid content in Dakota Amber sorgo by C. J. Franzke, of the South Dakota Agricultural Experiment Station, Brookings, S. Dak., has been in progress for some years. Seed of a strain (No. 39-30-S) having a low HCN content was obtained from Mr. Franzke and planted at Dalhart, Tex., in comparison with the unselected Dakota Amber variety. Three collections of the two

Table 6.—Hydrocyanic acid content of a Dakota Amber sorgo selection 39-30-S in comparison with that of unselected Dakota Amber, feterita, and Sudan grass grown at Dalhart, Tex. in 1937

Variety	HCN content in 100 g of oven-dry tissue		
	Whole Plants		Leaves
	August 6	August 13	September 10
	mg	mg	mg
Dakota Amber sorgo (selection 39-30-S)	161.7	61.7	66.8
Dakota Amber sorgo (unselected)	217.1	204.8	181.3
Feterita	254.3	232.3	200.6
Sudan grass	77.6	67.5	9.3

strains were analyzed and the results are shown in Table 6 in comparison with feterita and Sudan grass collected the same day. The Sudan grass was older than the sorghum varieties and, consequently, not strictly comparable.

The first collection was made on August 6, 1937, when the sorghum plants were about 14 inches and the Sudan grass about 24 inches in height. The data indicate that the selected strain, which also was earlier in maturity, is distinctly lower in HCN than unselected Dakota Amber and, in some cases, may be as low as Sudan grass. Despite this, the HCN content of the August 6 sample of selection No. 39-30-S (31.7 mg on a green basis) was above the supposedly toxic limit of 20 mg.

ENVIRONMENTAL DIFFERENCES

The relative standing of the various stations with reference to the quantities of HCN found in the plants in 1936 was determined by averaging the determinations shown in Table 3 of Sumac (or Early Sumac) and Dwarf Yellow milo (or Finney milo) at each station. The average HCN contents thus determined were as follows: Woodward, 60.0; Chillicothe, 32.7; Akron, 30.2; Hays, 26.1; Dalhart, 24.8; Tucumcari, 14.1. The high values at Woodward are due in part to the limited number of collections made only in August at a stage when the HCN content was high. A direct comparison of differences between

TABLE 7.—HYDROCYANIC ACID CONTENT OF WHOLE PLANTS OF HEGARI GROWN AT DIFFERENT STATIONS IN 1937

Station	Number of samples	Age at first sample	Average HCN content[1]
		Days	mg
Tucumcari, N. Mex.	16	34	188.0
Dalhart, Tex.	14	36	175.1
Chillicothe, Tex.	14	35	140.0
Akron, Colo.	16	37	117.0
Woodward, Okla.	16	38	114.4
Average		36	146.8

[1] Mg per 100 g dry matter.

stations was obtained in 1937 from collections of whole plants of hegari made during an eight-week period between July 20 and September 17. The data are shown in Table 7. On the basis of the average HCN content of hegari at five stations, Tucumcari and Dalhart are highest and Woodward and Akron lowest. The comparative ratings for the stations in 1937 show some striking differences from those for 1936 (Table 8). Tucumcari moved from sixth to first place, Dalhart from fifth to second, Woodward from first to sixth,

TABLE 8.—RELATIVE RANK OF STATIONS FOR HCN COMPARED WITH PRECIPITATION AND TEMPERATURE

Station	Altitude (feet)	Relative rank for HCN content of sorghum		Precipitation (inches) July and August		Precipitation (inches) June, July and August		Mean temperature °F. July and August	
		1936	1937	1936	1937	1936	1937	1936	1937
Tucumcari, N. Mex.	4,158	6	1	6.42	1.73	8.43	4.15	79.5	81.0
Dalhart, Tex.	3,978	5	2	1.74	2.95	4.81	4.18	79.0	79.5
Chillicothe, Tex.	1,406	2	3	0.46	4.72	1.68	5.58	87.0	86.0
Hays, Kans.	2,000	4	4	2.49	6.86	3.09	3.71	84.5	83.0
Akron, Colo.	4,560	3	5	4.02	3.51	7.06	5.91	76.5	76.0
Woodward, Okla.	2,002	1	6	.77	2.79	3.14	6.40	87.5	86.0

Chillicothe from second to third, and Akron from third to fifth. While comparable figures for whole hegari were not available from Hays in 1937 the general result from all varieties shows that Hays was running slightly above Akron, which would place this station in fourth place, as in 1936.

These changes may be in part correlated with the rainfall for the months of July and August, the period in which rainfall would be most likely to affect the averages for HCN in the sorghums. In both years the two highest-standing stations were relatively low in rainfall, but otherwise little relationship between rainfall and HCN is evident. It is possible that, above a critical point, available moisture may lead to HCN production by stimulating the growth of new tissue. In plants that have not begun to produce heads, HCN production in excess of utilization may be correlated with rapid growth of new tissues.

In this connection the results obtained with feterita and Sharon kafir grown at Arlington, Va. in 1937 are of interest. The crops were grown on low flat land with a high water table, and the season was unusually wet. At no time was the ground dusty and much of the time the surface was moist to muddy. Under these conditions the average HCN content for young whole feterita plants was 204 mg per 100 g of dry matter as compared with the average of 182.6 for the western stations (Table 5), and for leaves 82.8 mg for Arlington and 165.3 mg for the western stations. The average HCN content of young whole Sharon kafir plants was 128.2 mg as compared with 88.4 mg for whole young plants from Woodward, and 40.1 mg for leaves, against an average of 86.1 mg for kafirs grown at four western stations. Samples of leaves of Sharon kafir were not taken at Woodward.

It thus appears that young plants grown on the Atlantic seaboard under adequate moisture conditions may still produce quantities of HCN comparable with those grown under drought conditions on the Great Plains, but the HCN production appeared to fall off more sharply when the plants began to mature.

No correlation between altitude and HCN content of sorghums grown at a station could be drawn, and the same is true of the mean temperatures for July and August of both years.

SUMMARY

Plant and leaf samples of 33 sorghum varieties grown at one or more of six stations in the Great Plains area in 1936 and 1937 were analyzed for HCN content at various stages of growth. It appears that any variety tested may contain sufficient HCN at times to be toxic to animals. Feterita, hegari, Chiltex, and Sumac sorgo tended to be high in HCN; milo, darso, Atlas sorgo, and Kansas Orange sorgo were intermediate; and Leoti sorgo and "African Millet" sorgo and a selected strain of Dakota Amber sorgo were rather low in HCN. Varieties of kafir showed wide variation, some being high and others low in HCN. The comparative rank among the stations in average

HCN content of the samples was different in the two seasons. The HCN content of the sorghums showed some tendency to be high where summer precipitation was lowest but there was no consistent relation between HCN content of sorghum and differences in temperature. Young feterita plants grown under abundant moisture conditions at Arlington, Va., contained as much HCN as the average for the six Great Plains stations where drought was severe.

The HCN content (calculated on a dry matter basis) of dried leaves of sorghum varieties ranged from about 12 percent to 75 percent of that of the whole green plant.

LITERATURE CITED

1. Briese, R. R., and Couch, J. F. *Preservation of cyanogenetic plants for chemical analysis.* Jour. Agr. Res. **57**: 81–107. 1938.
2. Brünnich, J. C. *Hydrocyanic acid in fodder plants.* Jour. Chem. Soc. **83**: 788–796. 1903.
3. Collison, S. E. *Prussic acid in sorghum.* Fla. Agr. Exp. Sta. Bul. **155**. 1919.
4. Finnemore, H., and Cox, C. B. *The amount of hydrocyanic acid in sorghum, Sudan grass, and some hybrids.* Jour. Roy. Soc. N. S. Wales **65**: 145–152. 1931.
5. Francis, C. K. *The poisoning of livestock while feeding on plants of the sorghum group.* Okla. Agr. Exp. Sta. Circ. Inf. **38**. 1915.
6. Furlong, J. R. *The estimation of hydrocyanic acid in feeding-stuffs and its occurrence in millet and Guinea corn.* Analyst **39**: 430–432. 1914.
7. Hindmarsh, W. L. *The lethal dose of hydrocyanic acid for ruminants.* Jour. Council Sci. and Indus. Res., Australia **3**: 12–13. 1930.
8. Martin, J. H., Couch, James F., and Briese, Reinhold R. *Hydrocyanic acid content of different parts of the sorghum plant.* Jour. Amer. Soc. Agron. **30**: 725–734. 1938.
9. Piedallu, A. *Le Sorgo.* Paris. 390 pp. 1923.
10. Schröder, J., and Damman, H. *Zur Kenntnis der aus verschiedenen Hisearten entwickelten Blausäuremengen.* Chem. Ztg. **35**: 1436–1437. 1911.
11. Swanson, C. O. *Hydrocyanic acid in Sudan grass.* Jour. Agr. Res., **22**: 125–138. 1921.
12. Willaman, J. J., and West, R. M. *Notes on the hydrocyanic acid content of sorghum.* Jour. Agr. Res. **4**: 179–185. 1915.
13. —— and West, R. M. *Effect of climatic factors on the hydrocyanic content of sorghum.* Jour. Agr. Res. **6**: 261–272. 1916.

ZOOLOGY.—*Predaceous nematodes of the genus* Aphelenchoides *from Hawaii.*[1]

J. R. Christie, U. S. Bureau of Plant Industry.

In a recent publication Linford and Oliveira[2] pointed out that certain species of the nematode genus *Aphelenchoides* Fischer, 1894 are predaceous and number among their prey other nemas including the root-knot nematode, *Heterodera marioni* (Cornu, 1879) Goodey, 1932. These investigators have been able to rear five species of predaceous *Aphelenchoides* on agar cultures where their feeding habits could be studied. A population of some other nematode was first established on these cultures to provide food for the predators. Linford and

[1] Received February 3, 1939.

[2] Science **85**: 295–297. 1937.